

VARIATION AND ONTOGENY OF SOME
OXFORDIAN AMMONITES: *TARAMELLICERAS*
RICHEI (DE LORIO) AND *CRENICERAS*
RENGGERI (OPPEL), FROM WOODHAM,
BUCKINGHAMSHIRE

by D. F. B. PALFRAMAN

ABSTRACT. Statistical and ontogenetic studies of *Taramelliceras richiei* (de Loriol) and *Creniceras renggeri* (Oppel) have shown identity in their early stages. Variation in protoconch size is consistent and small, as is the diameter of the nepionic constriction. Divergence in shell form occurs only at the onset of maturity, which in *C. renggeri* begins at about 8.4 mm. and in *T. richiei* at about 18.8 mm. It is concluded that the two 'species' are a sexually dimorphic pair. The name *C. renggeri* has priority.

A COLLECTION of Lower Oxfordian ammonites was made from the Woodham Brick Company's Pit, with the objective of studying the variation and ontogeny of selected species. The pit is situated almost midway between Bicester and Aylesbury, near Ake-man Street Station, Buckinghamshire (Grid. Ref. 707186), and exposes some seventy feet of Oxford Clay (Arkell 1939). A lithological unit 'The Lamberti Limestone', a bed one foot thick, separates the lowermost forty feet of clay (Athleta Zone) from the uppermost thirty feet (Mariae Zone).

The Mariae Clays, as the beds of the Mariae Zone are here named, furnished the material studied. Both 'species' examined in this paper occur, together, throughout the Mariae Clays at Woodham; they are commonest in the lower ten feet of the Mariae Zone (generally pyritized), becoming rare in the upper twenty feet of beds (generally limonitized). They are both found together at all levels at Woodham. There is no evidence to suggest that either *Taramelliceras richiei* (de Loriol) or *Creniceras renggeri* (Oppel) occurs outside the Mariae Zone in this country. However, both species appear to have arisen in the Upper Lamberti Zone, being found in Haute-Saône (Maire 1908). They are both found together in the Renggeri Marls (Mariae and Cordatum Zones) of the Jura Mountains, where they are fairly common (de Loriol 1898-9, 1900 and Arkell 1939). As far as the author is aware they are not recorded above the Cordatum Zone; though, as Arkell (1939) says '... exact details of range [are] usually not available'.

All the specimens collected are preserved as internal moulds, pyritic near the base of the zone becoming limonitic towards the top. No original shell material has been found among the collection of several thousand ammonites. In a few individuals the innermost whorls are calcified, but rarely to a diameter of more than 3-4 mm. Some, which are otherwise completely pyritized or limonitized, were found to have a calcareous protoconch.

Very few specimens were found preserved as pyrite or limonite moulds above a maximum diameter of 2 or 3 cm. and it seems that there is a maximum size above which ammonites were not pyritized or limonitized. Internal moulds composed of clay, seen *in*

situ, showed that some ammonites must have had a diameter of not less than forty centimetres (see Pl. 48, fig. 1); often in the centre of such moulds were to be seen pyritized or limonitized nuclei of familiar dimensions.

Nearly five hundred specimens of *Taramelliceras richei* (de Loriol) and over two hundred specimens of *Creniceras renggeri* (Oppel) have been examined in this work. All specimens collected by, or given to, the author are in the University Museum, Oxford and are prefixed by OUM, those borrowed from the British Museum (Natural History) by BM. The following abbreviations are also used throughout the text: D = diameter, W = whorl width, HH = whorl height, U = umbilical diameter.

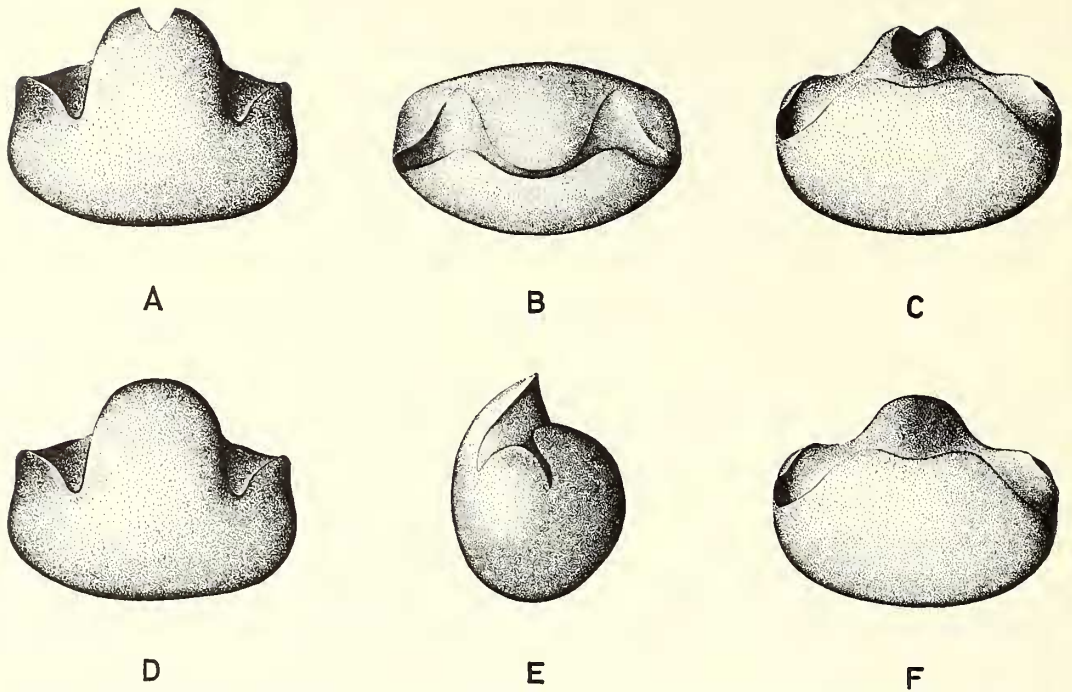
VARIATION AND ONTOGENY OF *TARAMELLICERAS RICHEI* (DE LORIOLO)

Due to the conditions of preservation, the most frequently occurring form in which *Taramelliceras richei* (de Loriol) was found at Woodham, was as internal moulds of the phragmocone. The type material of *T. richei* is based largely on internal moulds of phragmocones (de Loriol 1898). In the author's collection of nearly five hundred specimens less than 10 per cent. have any part of the body chamber preserved, and in none of these is it complete. The species is a typical oppelid, being compressed and involute with a small umbilicus. Whorl height is approximately half the diameter, whorl width is approximately quarter the diameter. Coiling is regular in the phragmocone, but on the body chamber of adults the umbilical seam begins to uncoil.

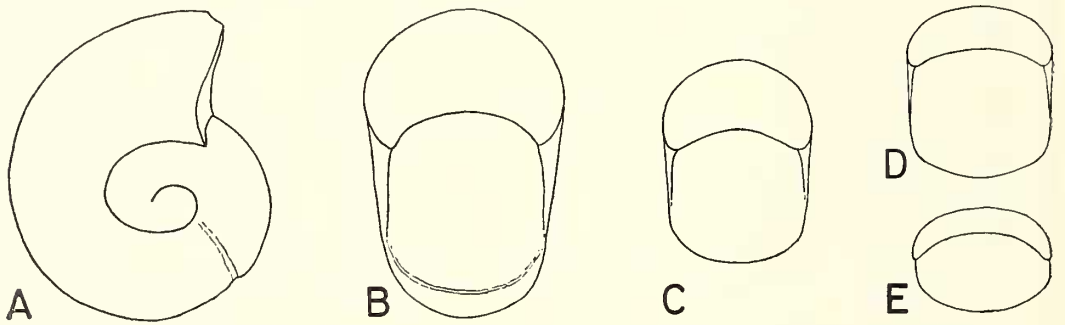
Protoconch. Less than 5 per cent. of the specimens of *T. richei* available were found to have protoconchs preserved; in all some eight protoconchs were dissected out. These are beautifully preserved as smooth pyritic moulds, showing details of the prosuture (text-fig. 1 and Pl. 48, fig. 4). In all cases the protoconchs are barrel-shaped with a width greater than the diameter. The largest recorded diameter of a protoconch of *T. richei* is 0.30 mm., the smallest 0.25 mm. (see Table 1). In one specimen (OUM J25230) the caecal mould is visible (text-fig. 1A, C).

Phragmocone. Just as the surface of the protoconch internal mould is smooth, so also is the first whorl of growth. The nepionic constriction occurs after one complete whorl of growth from the proseptum, at a diameter of about 0.53 mm., or roughly twice that of the protoconch (Table 1).

The nepionic constriction is well-defined, especially in the ventral and ventro-lateral regions, fading on the flanks and almost imperceptible near the umbilicus (text-fig. 2A, B; Pl. 48, fig. 6). In *T. richei* there is no ornamental difference, on the internal mould, between the whorl preceding the nepionic constriction and that immediately succeeding. In some ammonites, *Kosmoceras* and *Garantiana*, Makowski (1962) noted that the ornamentation characteristics of the full-grown shell appeared after the nepionic constriction. Ontogenetic features of note are: a decrease in the W/D ratio from the protoconch to a diameter of 0.8–1.0 mm. and a similar decrease in the U/D ratio to about the same diameter. From a diameter of 0.8–1.0 mm. onwards, growth is almost isometric until the onset of maturity which occurs at a diameter of about 18–20 mm. This is graphically represented here (text-figs. 3 and 4). From a diameter of 0.8–1.0 mm. until the onset of maturity the HH/D ratio shows almost isometric growth (text-fig. 5).



TEXT-FIG. 1. Protoconchs of *Taramelliceras richei* (de Loriol); Mariae Zone, Woodham, Bucks., England. A and D, ventral view; B, inclined apertural view; C and F, apertural view; E, side view. A and C based on OUM J25230; B, D, E, and F based on OUM J25228. All $\times 100$.



TEXT-FIG. 2. Diagram of the innermost whorls of *Taramelliceras richei* (de Loriol); Mariae Zone, Woodham, Bucks., England. A and B, showing the position of the nepionic constriction; E, protoconch. A, B, C, and D, drawn from OUM J25038; E, drawn from OUM J25234. All $\times 50$.

Ribbing is completely absent until a diameter of about 4 mm.; at this diameter radial umbilical swellings begin, strongly near the umbilicus but fading on the flanks. The ribs are shallow and distant and are initially eight to ten per whorl. It is not until a diameter of about 8–10 mm. that ribbing is differentiated into primaries and intercalatories (Pl. 50, fig. 1a, c).

TABLE I. Measurements in millimetres of the dimensions of protoconchs and the diameter of the nepionic constriction in specimens of *Taramelliceras richei* (de Loriol). All specimens from University Museum, Oxford (OUM). All specimens from the Mariae Zone, Woodham.

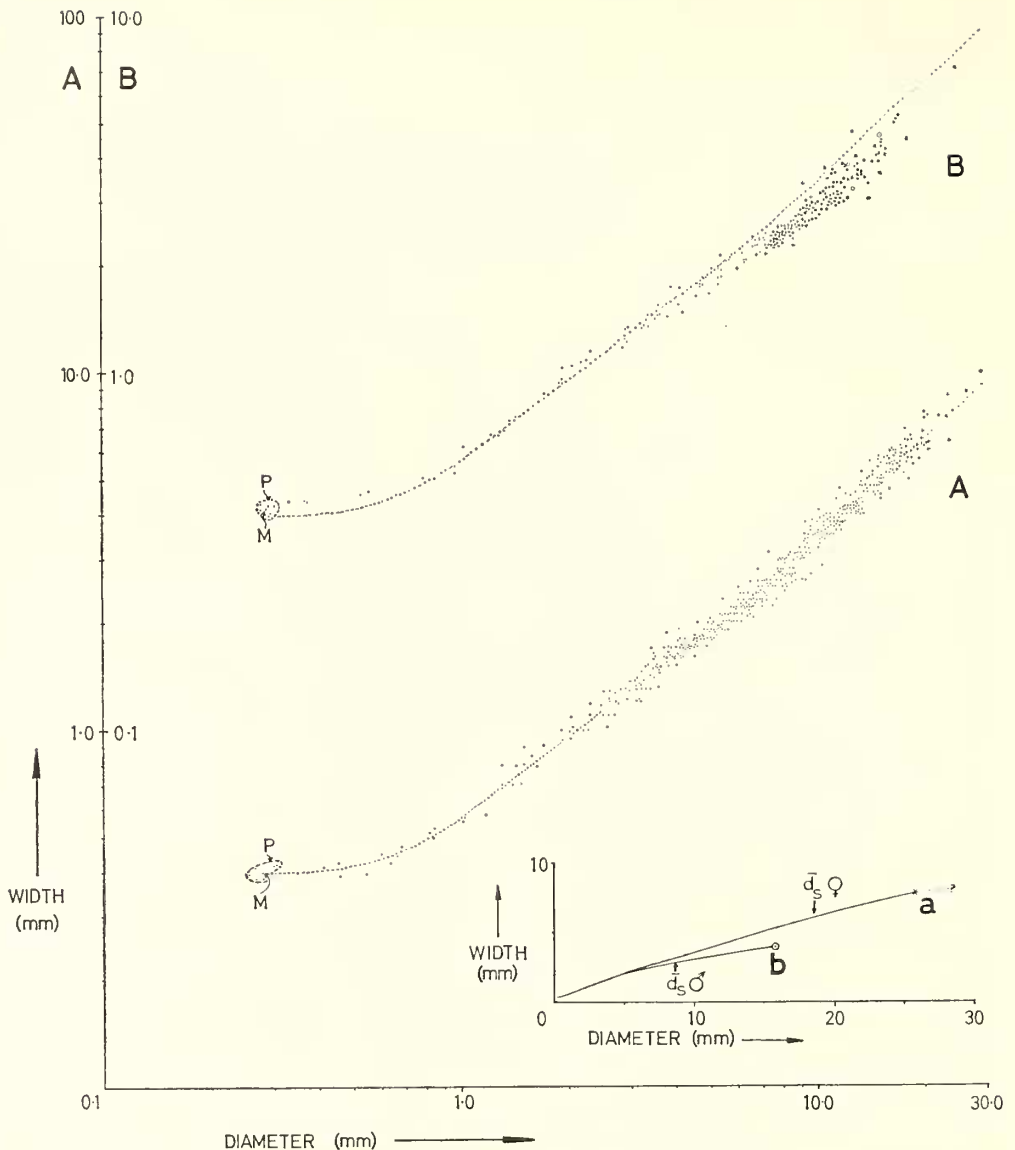
Specimen Number	Protoconch		Nepionic Constriction
	D	W	D
J25024			0.53
J25038			0.54
J25040	0.28	0.40	0.54
J25042			0.54
J25045	0.27	0.38	
J25046	0.25	0.40	0.56
J25228	0.30	0.42	0.53
J25230	0.30	0.42	0.53
J25231	0.28	0.41	0.52
J25232	0.27	0.41	0.52
J25234	0.28	0.38	0.53

Differentiated ribbing is undoubtedly a characteristic of *T. richei*, all specimens showing this feature to some degree, with a variation from relatively coarse ribbing to fine (Pl. 49, figs. 1a, b, 2a, c). On the final whorl of all adult specimens there are two series of ribs; primaries and intercalatories. The primary ribs generally number ten to twelve per whorl, developing initially as radial umbilical swellings then fading on the flanks and finally becoming relatively sharp and distinct on the ventro-lateral area. They are slightly sinuous with marked ventro-lateral prorsiradiation (Pl. 48, fig. 2a; Pl. 49, figs. 1a, 2a, 4a; Pl. 50, fig. 1a). Ribs always fade on the venter of internal moulds, but may not do so on the actual surface of the shell. In some cases the venter is smooth (see Pl. 49, fig. 1b), whereas in most instances the ribbing simply becomes weaker in the ventral region (Pl. 49, fig. 2b). On the last quarter of the adult phragmocone whorl, nearly all specimens develop feeble ventral tubercles, which become stronger adorally (Pl. 49, fig. 4a, b; Pl. 50, fig. 1a, b). The tubercles coincide at the point at which opposing ribs, on either side of the venter, both primaries and intercalatories, would meet had they continued uninterrupted across the venter.

The intercalatory ribs, on the final whorl of adult specimens, generally number about forty. They are restricted to the ventro-lateral area and are identical in form with the primary ribs in this region, by way of amplitude, sharpness and direction, for each particular specimen. Between each primary rib are three to four intercalatories (Pl. 48, fig. 2a; Pl. 49, figs. 2a, 4a; Pl. 50, fig. 1a).

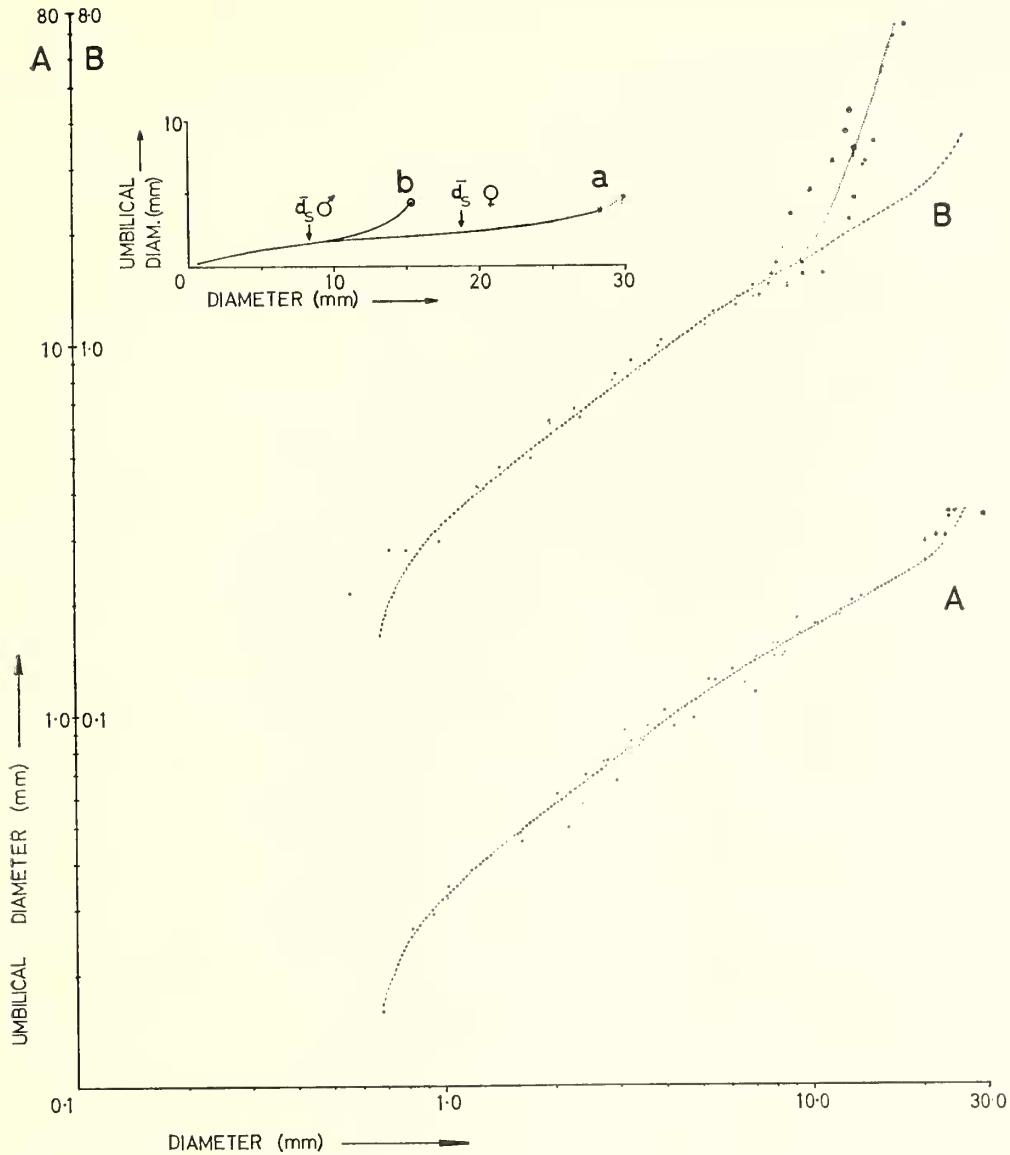
The mean maximum diameter of the phragmocone, of more than two hundred adult specimens, was found to be 18.8 mm., with a standard deviation (σ) of 1.51. The coefficient of variation ($V = 100\sigma/m$, where m is the mean maximum diameter, \bar{d}_s , of the adult phragmocones) is 8.02. The greatest diameter at which the septa are approximated was found to be 27 mm., the smallest 14 mm. (text-fig. 6). The phragmocone generally comprised $6\frac{1}{4}$ –7 whorls from the prosepium. Variation in the whorl-shape is here shown diagrammatically (text-fig. 7 and Pl. 48, fig. 2a).

The sutural ontogeny of *T. richei* develops in a way which, in Jurassic ammonites, is beginning to appear fundamental (Schindewolf 1954). The prosuture is significantly



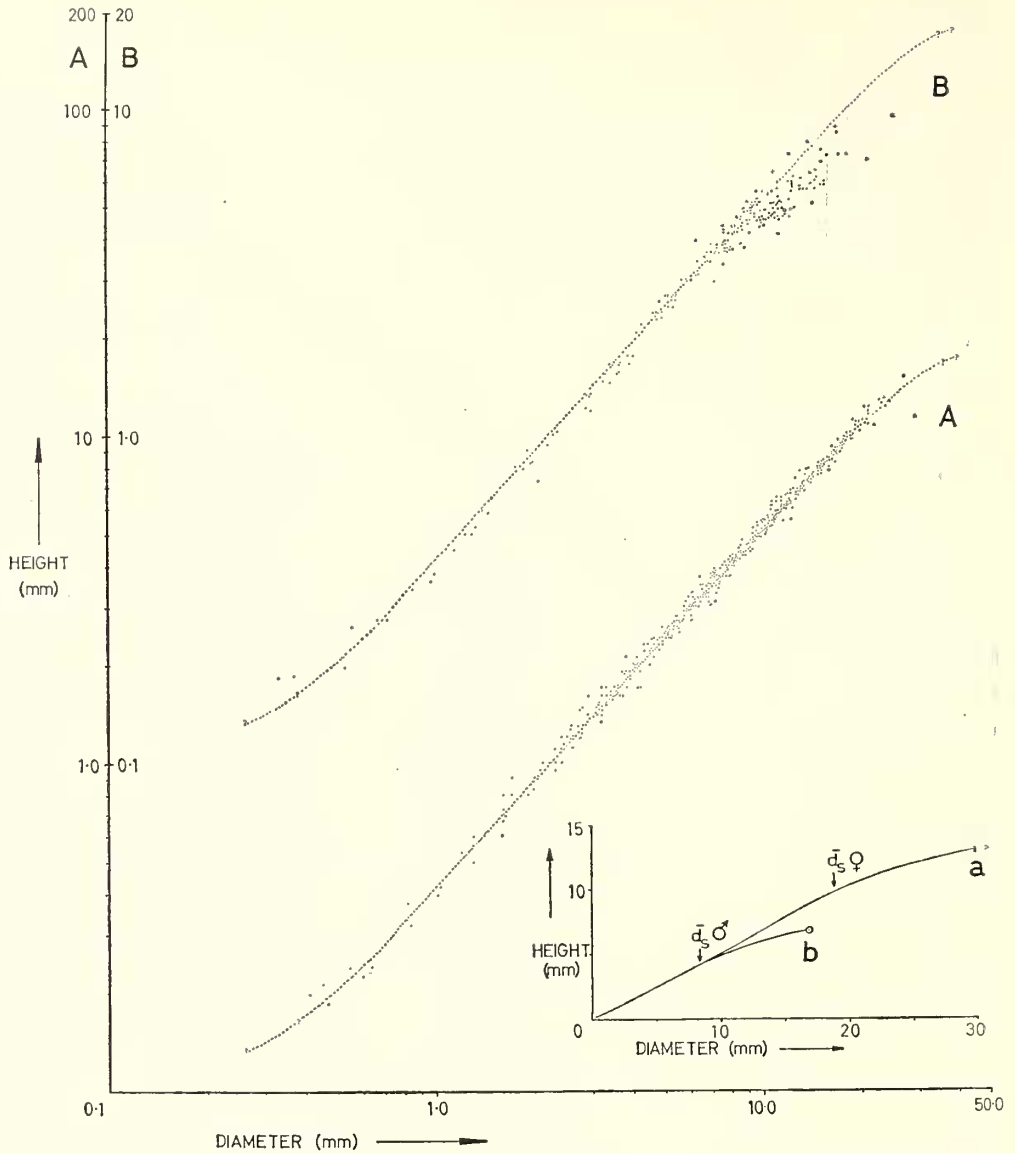
TEXT-FIG. 3. Graphs showing the relationship between diameter and whorl width of *Taramelliceras richei* (de Loriol), and of *Creniceras renggeri* (Oppel). The two graphs are superimposed: the diameter axis is common, the width axis is divided into A and B scales, the B scale being one log cycle behind the A scale. Graph A (W/D for *T. richei*) is controlled by the A scale, graph B (W/D for *C. renggeri*) is controlled by the B scale. The fine dashed line on graph B is that superimposed from graph A (approximate best-fit line). The areas denoted by P (coarse dashed line) enclose measurements made on the protoconchs: M is the mean of these measurements. Encircled dots represent measurements made at the maximum diameter of complete adults: asterisks—measurements made on adult body-chambers: crosses—measurements made at the adoral end of adult phragmocones: dots—measurements made on immature phragmocones.

Inset. The same graphs plotted on a linear scale and having both axes common. a, W/D for *T. richei*; b, W/D for *C. renggeri*. The arrowed points, $\bar{d}_s \text{♀}$ and $\bar{d}_s \text{♂}$, mark the position of the mean septate diameter of mature specimens of supposed female and male respectively. All specimens from the Mariae Zone, Woodham.



TEXT-FIG. 4. Graphs showing the relationship between diameter and umbilical diameter of *Taramelliceras richei* (de Loriol), and of *Creniceras renggeri* (Oppel). The two graphs are superimposed: the diameter axis is common, the umbilical diameter axis is divided into A and B scales, the B scale being one log cycle behind the A scale. Graph A (U/D for *T. richei*) is controlled by the A scale, graph B (U/D for *C. renggeri*) is controlled by the B scale. The fine dashed line on graph B is that superimposed from graph A (approximate best-fit line). Conventions as for text-fig. 3.

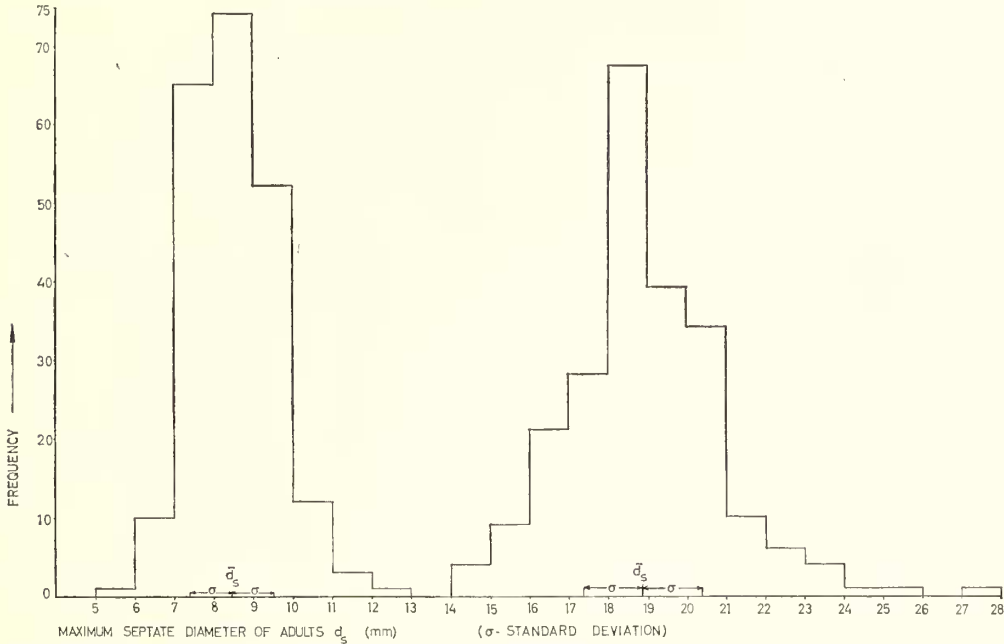
Inset. The same graphs plotted on a linear scale and having both axes common. *a*, U/D for *T. richei*; *b*, U/D for *C. renggeri*. The arrowed points, $\bar{d}_s \text{♀}$ and $\bar{d}_s \text{♂}$, mark the position of the mean septate diameter of supposed female and male respectively. All specimens from the Mariae Zone, Woodham.



TEXT-FIG. 5. Graphs showing the relationship between diameter and whorl height of *Taramelliceras richei* (de Loriol), and of *Creniceras renggeri* (Oppel). The two graphs are superimposed: the diameter axis is common, the height axis is divided into A and B scales, the B scale being one log cycle behind the A scale. Graph A (HH/D for *T. richei*) is controlled by the A scale, graph B (HH/D for *C. renggeri*) is controlled by the B scale. The fine dashed line on graph B is that superimposed from graph A (approximate best-fit line). Conventions as for text-fig. 3.

Inset. The same graphs plotted on a linear scale and having both axes common. *a*, HH/D for *T. richei*; *b*, HH/D for *C. renggeri*. The arrowed points, $\bar{d}_s \text{♀}$ and $\bar{d}_s \text{♂}$, mark the position of the mean septate diameter of mature specimens of supposed female and male respectively. All specimens from the Mariee Zone, Woodham.

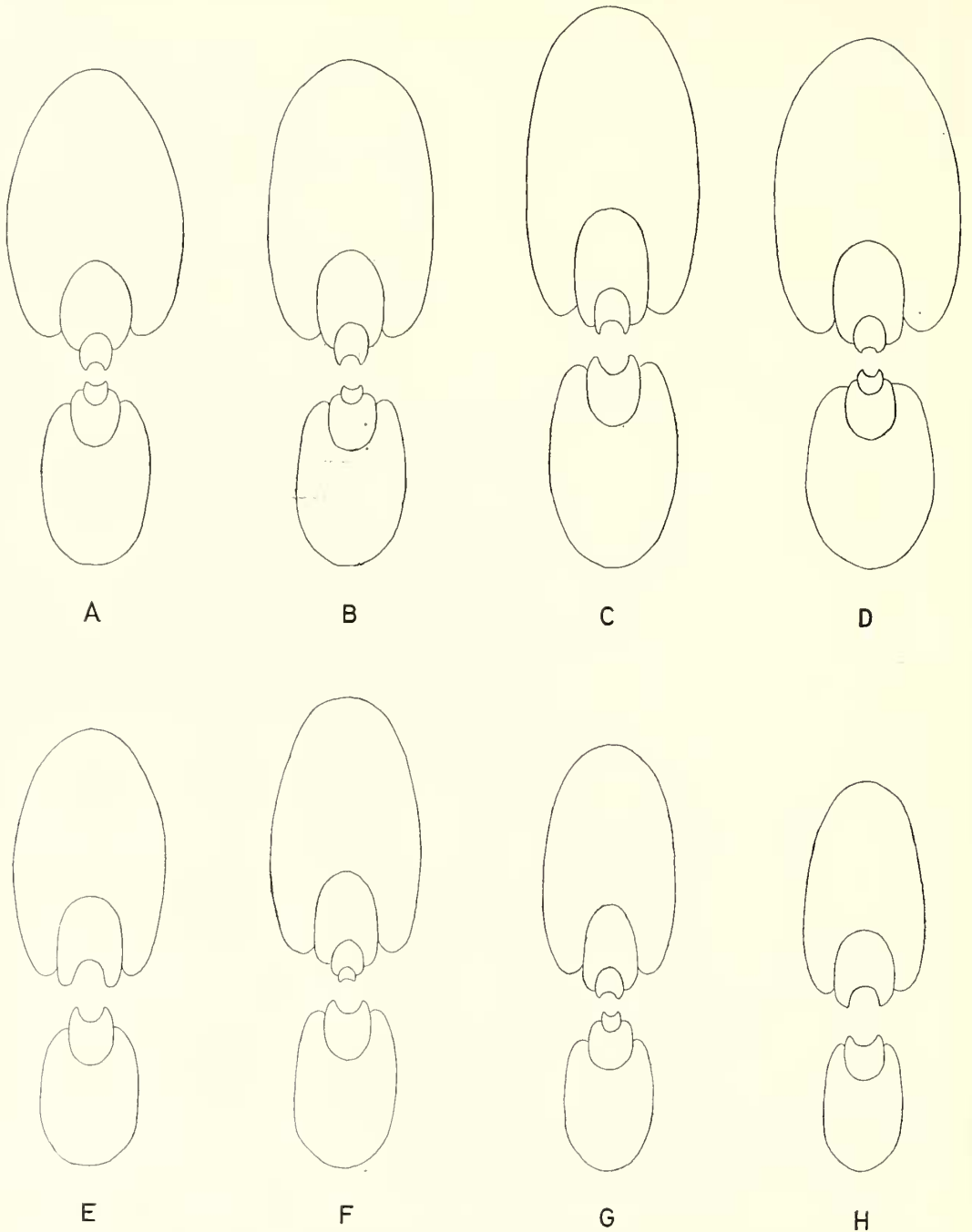
different from the primary suture, having a very large ventral saddle. The primary suture (text-figs. 1 and 8) is divided into: external (or ventral), lateral, U_2 , U_1 , and dorsal lobes, with corresponding saddles between. These first-formed lobes have been called 'protolobes' by Schindewolf (1954): subsequent works (Schindewolf 1960, 1962, and 1963) have shown that these basic protolobes are common to all Jurassic ammonites so far investigated. Addition of successive sutural elements in *T. richei* occurs at the



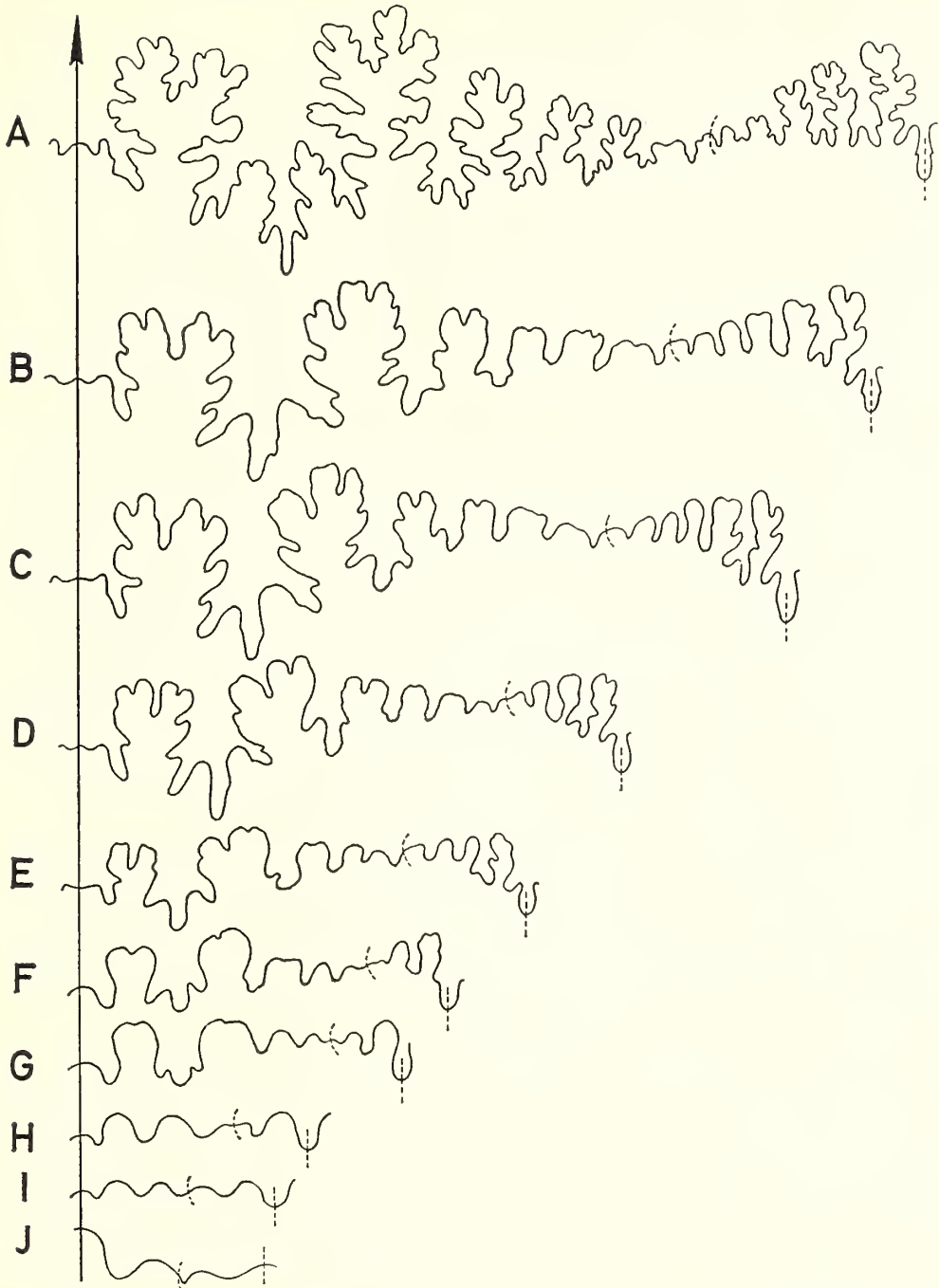
TEXT-FIG. 6. Histogram showing the variation in the diameter at which septation ceases (d_s) in mature specimens of *Taramelliceras richei* (de Loriol) and in *Creniceras renggeri* (Oppel). The *T. richei* range is from 14–28 mm., the *C. renggeri* range from 5–13 mm. All specimens from the Mariae Zone, Woodham.

umbilical seam; this is the 'U-type' ontogeny of Schindewolf (1954). The final sutures of adult specimens are greatly differentiated into several complex saddles and lobes (text-fig. 8A). Sutural approximation, generally regarded as a feature of maturity, is commonly to be seen in most specimens with a phragmocone diameter of 18–19 mm. (Pl. 48, fig. 2a; Pl. 49, figs. 2a, 4a, 4b; Pl. 50, fig. 1a).

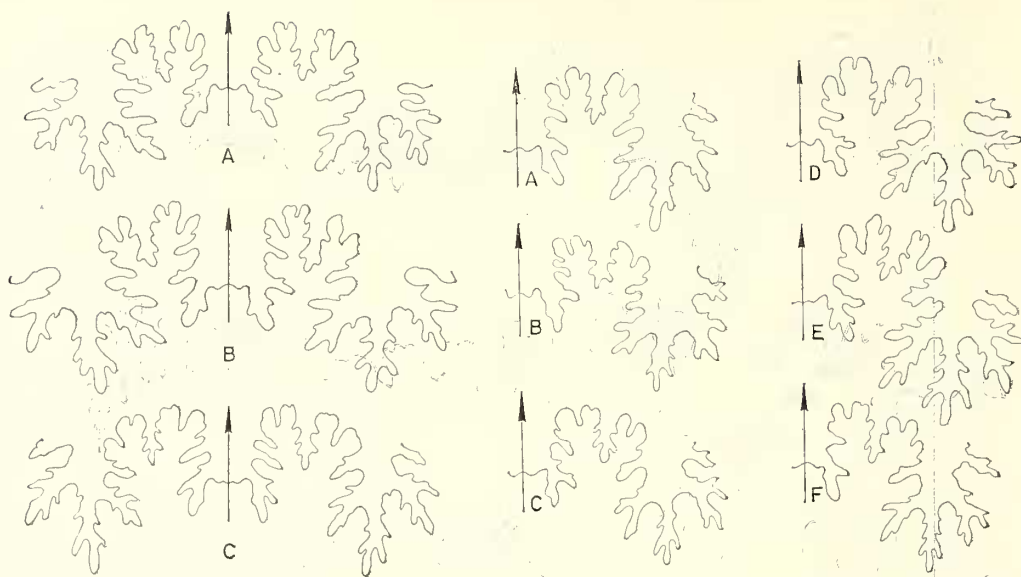
In the adult sutures the largest saddles are the first and second lateral and the largest lobes the ventral and lateral. These major sutural elements show the greatest range of variation and have been compared on either side of the venter in the same specimen, and on the same side of the venter at similar diameters, in different specimens. Comparing the same sutural elements, on either side of the venter for any single specimen, shows remarkably little variation (text-fig. 9). The greatest difference recorded is in the frilling of the most adapical accessory lobe: even so this difference is somewhat subtle and does not compare with the wide intraspecific sutural variation shown by *Morrisiceras morrisi* (Oppel) and *Clydoniceras discus* (Sow.) mentioned by Arkell (1957).



TEXT-FIG. 7. Cross-sections through the phragmocone of *Taramelliceras richei* (de Loriol). A, OUM J25041; B, OUM J25021; C, OUM J25010; D, OUM J25239; E, OUM J25241; F, OUM J25236; G, OUM J25005; H, OUM J25238. All $\times 4$. All specimens from the Mariae Zone, Woodham.



TEXT-FIG. 8. Sutural ontogeny of *Taramelliceras richei* (de Loriol). A, OUM J25013, $\times 9$ ($D = 15$ mm.); B, OUM J25036, $\times 15$ ($D = 8.7$ mm.); C, OUM J25036, $\times 18$ ($D = 6.4$ mm.); D, OUM J25036, $\times 20$ ($D = 4.6$ mm.); E, OUM J25036, $\times 25$ ($D = 3.13$ mm.); F, OUM J25036, $\times 30$ ($D = 2.13$ mm.); G, OUM J25036, $\times 35$ ($D = 1.53$ mm.); H, OUM J25036, $\times 50$ ($D = 0.85$ mm.); I, OUM J25040, $\times 50$ ($D = 0.32$ mm.); J, OUM J25040, $\times 50$ ($D = 0.28$ mm.). i, primary suture. j, prosuture. All specimens from the Mariae Zone, Woodham.



TEXT-FIG. 9.

TEXT-FIG. 10.

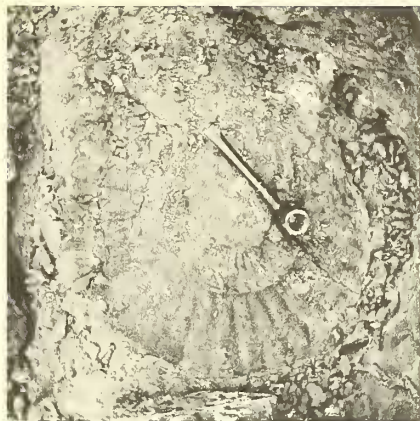
TEXT-FIG. 9. Sutural variation in *Taramelliceras richei* (de Loriol). A, OUM J25230 (D = 12.2 mm.); B, OUM J25228 (D = 12.0 mm.); C, OUM J25229 (D = 12.1 mm.). All $\times 7.5$. All specimens from the Mariae Zone, Woodham.

TEXT-FIG. 10. Sutural variation in *Taramelliceras richei* (de Loriol). A, OUM J25029 (D = 12 mm.); B, OUM J25028 (D = 12.4 mm.); C, OUM J25009 (D = 11.8 mm.); D, OUM J25035 (D = 12 mm.); E, OUM J25024 (D = 12 mm.); F, OUM J25026 (D = 12 mm.). All $\times 7.5$. All specimens from the Mariae Zone, Woodham.

Variation between the same sutural elements of different specimens, at approximately the same diameter, shows relatively marked differences (text-fig. 10). These differences are generally of size, however, the disposition of the elements being essentially the same. The most marked differences are between the specimens OUM J25029 and OUM

EXPLANATION OF PLATE 48

- Fig. 1. Internal clay mould of a large *Peltoceras*(?) sp.; basal Mariae Zone (about 5 ft. above the Lamberti Limestone), Woodham, Bucks. $\times \frac{1}{10}$.
- Fig. 2. *Taramelliceras richei* (de Loriol, OUM J25571. Adult phragmocone. a, side view; b, apertural view. Both $\times 3$.
- Fig. 3. *T. richei*, BM C. 39588; Oxford Clay, Scarborough, Yorkshire. $\times 1$.
- Fig. 4. *T. richei*, OUM J25234 (lost); Mariae Zone, Woodham, Bucks. Protoconch. $\times 50$.
- Fig. 5. *T. richei*, OUM J25672. Adult specimen. a, side view; b, ventral view. The body-chamber occupies about $\frac{1}{3}$ of the final whorl. Both $\times 3$.
- Fig. 6. *T. richei*, OUM J25038. Innermost whorls showing the nepionic constriction. $\times 40$.
- Fig. 7. *T. richei*, BM 39642; Oxford Clay, Scarborough, Yorkshire. Stereopair of adult specimen showing the nature of the peristome and ventro-lateral spines. $\times 1$.
- Fig. 1—unwhitened; Figs. 2a, b, 3, 5a, b, and 7—whitened with ammonium chloride; Figs. 4 and 6—whitened with magnesium oxide. All specimens from the Mariae Zone, Woodham, Bucks., unless otherwise stated.



1



2a



2b



3



5a



5b



4



6



7



J25024 (text-fig. 10A, E). Generally speaking it seems fairly safe to say that the intra-specific sutural variation in *T. richei* is extremely small.

Body-chamber. The body-chamber of adult specimens of *T. richei* is quite different from the phragmocone. The most marked change is in the development of ventral and ventro-lateral spines. In some specimens spines develop quite suddenly after the last septum in both positions. Specimen OUM J25676 shows the ventral spines beginning first, the ventro-lateral spines developing later (Pl. 49, fig. 3a, b). The ventro-lateral spines are paired and alternate with those on the venter, relative to the median plane. Not all body-chambers, of specimens which are otherwise identical, become spinose: they merely retain the ventral tubercles of the adult phragmocone (Pl. 48, fig. 5a, b). However, there is probably a whole range between tuberculate venters only, and spinose venters and ventro-lateral regions: this is supported by a collection of specimens from the Oxford Clay of Warboys, Hunts. (BM C.4333, C.10651, C.15960, C.16009, C.16010, C.19286, and C.19296), which shows precisely this range.

Ribbing on the body-chamber appears to be weaker than on the phragmocone, but the very poor preservation of the body-chambers of Woodham specimens may affect this feature. Some of the better preserved specimens from Warboys show well-defined ribs, both primaries and intercalatories, even on the flanks of the body-chamber (BM C.4333 and C.15960). The phragmocones of these specimens are otherwise identical with those from Woodham.

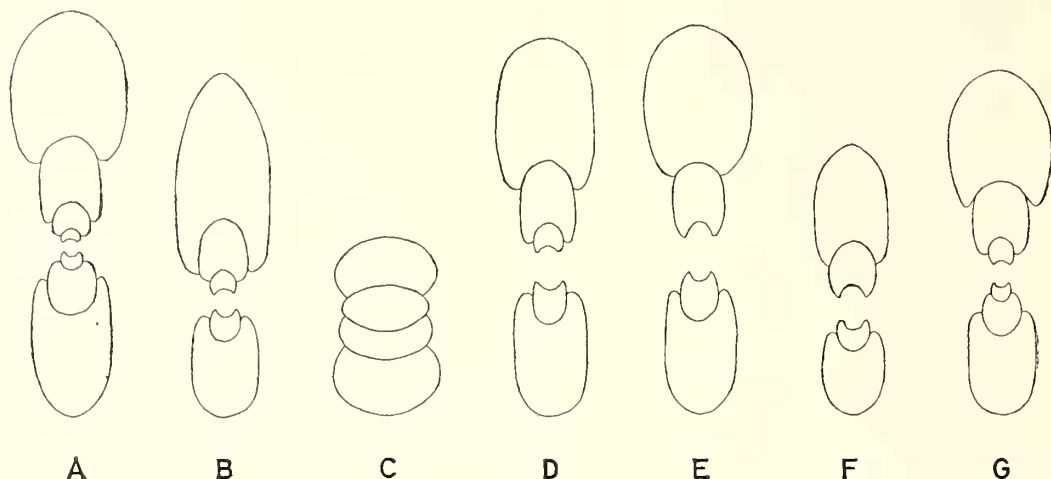
As would be expected in the final stages of adult specimens, the body-chamber uncoils at the umbilical seam (Pl. 49, fig. 3b and text-fig. 4). Among the Woodham specimens the author was unable to find an adult which showed the nature of the peristome. However, among three specimens from the Oxford Clay of Scarborough, Yorkshire (BM 39642, C.39588, and C.39589), labelled *Proscaphites oculatus* (Phillips), is one specimen (BM 39642) which shows the nature of the peristome (Pl. 48, fig. 7). These specimens are almost certainly conspecific with *T. richei*, developing ventral and ventro-lateral spines (Pl. 48, figs. 3 and 7): unfortunately the phragmocone is not preserved and the body-chamber of the specimens is crushed. The peristome of BM 39642 is fairly simple, its outline coinciding with the course of the primary ribs. The diameter of the almost complete specimen (45 mm.), which has a body-chamber of three-quarters of a whorl, is in agreement with the predicted size of complete adults from Woodham, assuming that the Woodham specimens have a body-chamber of about three-quarters of a whorl. If this is so, the total number of whorls from the proseptum is from $7-7\frac{3}{4}$ in *T. richei*.

Among the better preserved specimens from Woodham, the phragmocone is a dull black colour, whereas that of the body-chamber is a golden reflective (if pyritic) mould. The dull black colour extends just on to the body-chamber, and in many cases a well-defined line can be traced between the black and golden parts of the body-chamber. The line is almost co-incident with the course of the primary ribs but with slightly greater ventral prorsiradiation. This line may represent the annulus (Crick 1898): however, no muscle-scars were recorded from any specimen of *T. richei* from Woodham.

VARIATION AND ONTOGENY OF *CRENICERAS RENGGERI* (OPPEL)

Creniceras renggeri is a smaller 'species' than *Taramelliceras richei*, complete adults rarely attaining a diameter of more than 20 mm. It appears that because of its small

size *C. renggeri* is generally to be found complete, or nearly so, as it rarely exceeds the optimum size for complete preservation as a pyritic or limonitic mould in the Oxford Clay of Woodham.



TEXT-FIG. 11. Cross-sections through *Creniceras renggeri* (Oppel) A, OUM J25294; B, OUM J25378; C, OUM J25378 (inner whorls of B); D, OUM J25298; E, OUM J25305; F, OUM J25322; G, OUM J25272. All except fig. C are $\times 4$; fig. C $\times 30$. All specimens from the Mariae Zone, Woodham.

TABLE 2. Measurements in millimetres of the dimensions of protoconchs and the diameter of the neponic constriction in specimens of *Creniceras renggeri* (Oppel). All specimens from the University Museum, Oxford (OUM). All specimens from the Mariae Zone, Woodham.

Specimen Number	Protoconch		Nepionic Constriction D
	D	W	
J25305	0.29	0.40	
J25308	0.30	0.42	
J25347	0.29	0.42	
J25364	0.28	0.41	0.54
J25368	0.28	0.42	0.53
J25378	0.29	0.41	0.56

Protoconch. Ontogenetically *C. renggeri* goes through identical stages as *T. richiei* until the onset of maturity. Protoconchs are identical in shape to, and vary within almost the same limits as, those of *T. richiei* (Table 2, cf. Table 1).

EXPLANATION OF PLATE 49

Taranelliceris richiei (de Loriol). All specimens are from the Mariae Zone of Woodham, Bucks. and have been whitened with ammonium chloride. All $\times 3$.

Fig. 1. OUM J25482. Adult phragmocone. *a*, side view; *b*, ventral view. Fig. 2. OUM J25617. Adult phragmocone. *a*, side view; *b*, ventral view. Fig. 3. OUM J25676. Adult specimen; the body-chamber occupies the last half-whorl; ventral and ventro-lateral spines are developed. *a*, ventral view; *b*, side view. Fig. 4. OUM J25455. Adult phragmocone. *a*, side view; *b*, ventral view.



1a



2a



3a



1b



2b



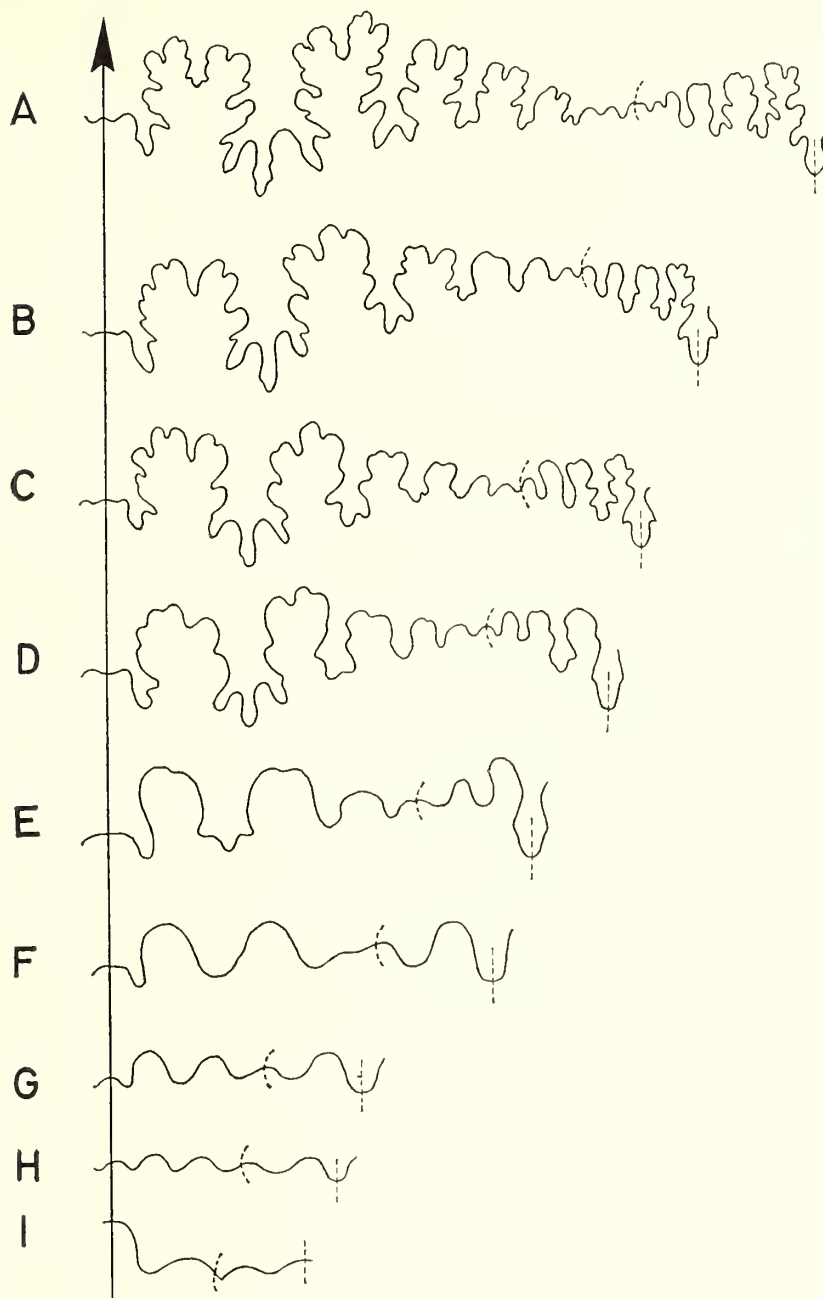
3b



4a



4b



TEXT-FIG. 12. Sutural ontogeny of *Creniceras renggeri* (Oppel). A, OUM J25244, $\times 12$ ($D' = 10.61$ mm.); B, OUM J25364, $\times 15$ ($D = 8.03$ mm.); C, OUM J25364, $\times 16$ ($D = 6.08$ mm.); D, OUM J25364, $\times 25$ ($D = 3.18$ mm.); E, OUM J25364 $\times 50$ ($D = 1.43$ mm.); F, OUM J25364, $\times 50$ ($D = 0.99$ mm.); G, OUM J25364, $\times 50$ ($D = 0.38$ mm.); H, OUM J25364, $\times 50$ ($D = 0.33$ mm.); I, OUM J25364, $\times 50$ ($D = 0.28$ mm.). H, primary suture. I, prosuture. All specimens from the Mariae Zone, Woodham.

Phragmocone. The nepionic constriction occurs at a diameter of between 0.53 mm. and 0.56 mm., compared with 0.52–0.56 mm. in *T. richei*. However, only three measurements of the nepionic constriction were available for *C. renggeri*, compared with ten for *T. richei*. The whorl shape (text-fig. 11) and sutural ontogeny (text-fig. 12) of *C. renggeri* vary within very similar limits to those of *T. richei* (text-figs. 7 and 8).

A complete lack of ornament occurs until a diameter of about 4 mm., where shallow, distant, radial, umbilical swellings develop. These swellings fade on the flanks and do not re-form on either the venter or ventro-lateral regions. These features are consistent with those recorded in *T. richei* at comparable diameters. The W/D, U/D, and HH/D ratios are identical to those of *T. richei* at similar growth stages (text-figs. 3, 4, and 5).

The final whorl of the phragmocone is, in most cases, seen only on removal of the body-chamber. Septation generally ceases at a diameter of 8–9 mm. The mean diameter at which septation ceases, in over two hundred adults, is 8.4 mm.: standard deviation (σ) is 1.1; coefficient of variation (V) is 12.8 (text-fig. 6). Specimen OUM J25246, with a maximum septate diameter of 17 mm., is almost certainly a very large adult *C. renggeri* (Pl. 50, fig. 5). However, variation in over two hundred specimens of *C. renggeri* is not continuous to such a large diameter, the range of continuous variation being 5–13 mm. (text-fig. 6), and it seems that the specimen in question is an extreme form.

The final whorl of the mature phragmocone is typically oppelid in character, being compressed and involute and with a narrow umbilicus. There are $4\frac{1}{2}$ – $5\frac{1}{2}$ complete whorls from the proseptum to the end of the phragmocone in adult specimens.

Radial umbilical swellings are developed, which fade on the flanks. These generally number about ten per whorl and are comparable with those, in number, direction, and nature, of *T. richei* at a similar diameter (Pl. 50, fig. 2*a, c* and cf. Pl. 50, fig. 1*c*). The ventro-lateral area is smooth, as is the venter, except on the final quarter whorl of adults, where feeble ventral tubercles are almost always developed. The tubercles become well-defined immediately before the beginning of the body-chamber (Pl. 50, figs. 2*a, 3*; Pl. 51, figs. 1*a, 2a, b*). Uncoiling of the umbilical seam in adults begins before the final septa are deposited (Pl. 50, figs. 2, 4, 5; and Pl. 52, figs. 2*b, 3, 5*), becoming markedly so on the body-chamber (Pl. 50, figs. 2*a, 3*; Pl. 51, figs. 2*a, 3*; Pl. 52, figs. 1, 3, and text-fig. 13).

Sutures were drawn at a diameter of approximately 8 mm. from nine specimens, showing the first and second lateral saddles and the ventral and lateral lobes. Differences in the same suture on either side of the venter are decidedly small (text-fig. 14); whereas

EXPLANATION OF PLATE 50

Fig. 1. *Taramelliceras richei* (de Loriol), OUM J25430. *a*, side view of adult phragmocone; *b*, ventral view of adult phragmocone; *c*, preparation of the inner whorls.

Figs. 2–4. *Creniceras renggeri* (Oppel). Fig. 2. OUM J25244. *a*, side view of adult specimen; *b*, ventral view of adult body-chamber; *c*, preparation of the inner whorls. Fig. 3. OUM J25360. Rostrate adult specimen. Fig. 4. OUM J25282. Body-chamber with almost complete peristome. *a*, side view; *b*, ventral view; *c*, apertural view.

Fig. 5. *C. renggeri* (?), OUM J25246. Giant adult male?

Specimens have been whitened with ammonium chloride. All from the Mariae Zone, Woodham, Bucks. All figs. $\times 3$.



1a



2a



2b



2c



1b



1c



3



4a



4b

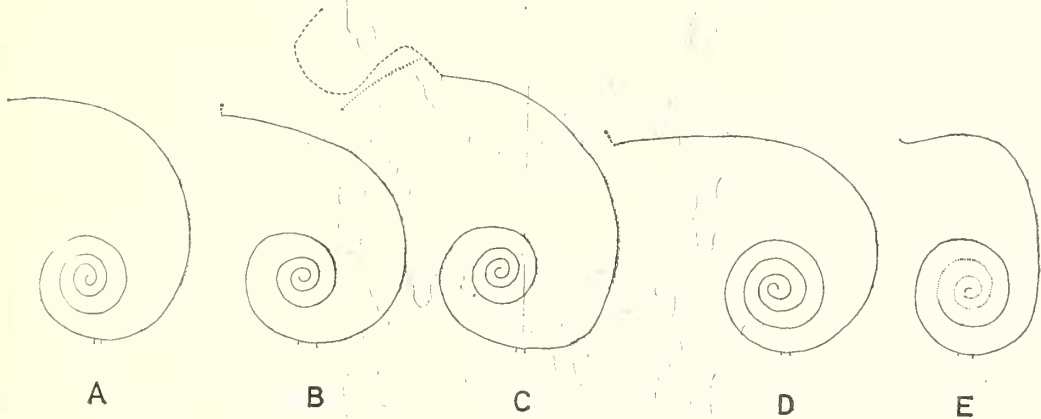


4c



5

differences between sutures of different specimens, drawn at approximately the same diameter, are more marked (text-fig. 15). The range of variation, qualitatively assessed, appears to be similar to that shown by *T. richei* (cf. text-figs. 9 and 10). Sutural approximation can clearly be seen in a large number of specimens (Pl. 50, figs. 2*a*, 3; Pl. 51, figs. 1*a*, 3*a*, 12; Pl. 52, figs. 2*a*, *b*, 3, 4, 5, 6).



TEXT-FIG. 13. Diagrams of the umbilical seam of *Creniceras renggeri* (Oppel). The positions of the last two sutures are indicated. C, position of venter and lappet indicated. A, OUM J20662; B, OUM J20673; C, OUM J25364; D, OUM J20675; E, OUM J25377. All $\times 10$. All specimens from the Mariae Zone, Woodham.

Body-Chamber. In nearly all specimens of *C. renggeri* a large proportion of the final whorl is body-chamber: in complete specimens the body-chamber occupies two-thirds to three-quarters of a volution (Pl. 51, figs. 2*a*, 4; Pl. 52, figs. 1-3, 5, 6). In complete adult specimens the total number of whorls, counting from the prosepium, is from $5\frac{1}{2}$ - $6\frac{1}{2}$. Morphology apart, the most striking difference between the body-chamber and phragmocone is that of colour. When pyritized the body-chamber is preserved as a golden reflective internal mould, whereas the phragmocone is a dull black colour. The body-chamber is frequently well preserved and some specimens have almost complete apertures.

Spiral striae are developed on the body-chamber of all adult specimens: this feature is particularly well seen on specimens OUM J25248, J25265 and J25392 (Pl. 51, fig. 3*a*; Pl. 52, figs. 2*a*, 6). The striation is only feebly developed on the phragmocone (Pl. 51, fig. 3*a*), if at all.

The ventral tubercles of the phragmocone give rise to large truncated spines on the venter of the adult body-chamber. A great deal of variation is to be seen between specimens concerning the spines. At one extreme a few specimens have perfectly smooth venters (Pl. 52, figs. 2, 4), while others develop enormous spines (Pl. 52, figs. 1, 5). Among the Woodham population, however, a complete range from smooth venters to coarsely spined ones is to be seen (Pl. 51, figs. 5-12 and Arkell 1939, pl. 9, figs. 15-27). The majority of specimens have spines similar to those of OUM J25392 (Pl. 52, fig. 6). In complete adults there are generally nine to twelve spines on the body-chamber; however, the total number depends largely on the size of the spines: specimens with finely denticulate venters having as many as twenty-four (Pl. 51, fig. 11).